DOUBLE-STAR ASTRONOMY

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DOUBLE-STAR ASTRONOMY:

CONTAINING

THE HISTORY OF DOUBLE-STAR WORK;

COMPUTATION OF ORBITS AND POSITION OF ORBIT-PLANES;

FORMULÆ IN CONNECTION WITH MASS, PARALLAX, MAGNITUDE, ETC.

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[*From* 'THE OBSERVATORY,' 1908.]

DOUBLE-STAR ASTRONOMY.

In attempting the history of any subject there is always the same initial difficulty to confront—where to begin. There is an inherent tendency to push back the date as far as possible, and sometimes a little further. This is true in the present instance. Stars must for ages have received attention because of their apparent proximity to each other. I think, however, we may fairly claim the year 1779 as the true beginning of double-star astronomy. In this year Sir W. Herschel commenced definitely the work which finally led to the discovery of the real nature of these neighbouring suns. True it is that he had at this time another purpose in view, and it is very difficult, if not impossible, to say when the real meaning of his labours disclosed itself to him. We might claim another century, for Riccioli noted ζ Ursæ Majoris as double about the middle of the 17th century, while Huyghens saw θ Orionis quadruple in 1656 *, and the duplicity of γ Arietis was detected by Hooke in 1664 †.

In addition to these it may be of interest to give the date of discovery of a few others which have become well known in our time :—

	Discovered by	
α Crucis	Fontenay	1685 ‡
α Centauri	Richaud	1689 §
γ Virginis	Bradley	1718
Castor	Bradley	1719
61 Cygni	Bradley	1753
ζ Cancri	Mayer	1756
ϵ Lyræ	Maskelyne	1765
α Herculis	Maskelyne	1777
70 Ophiuchi	Herschel	1779
ξ Ursæ Majoris	Herschel	1781

The discovery of α Centauri is usually ascribed to Feuillée ‖ in 1709, from the fact that he was the first to give an estimate of

* Huyghens, 'Opera,' p. 540. † Phil. Trans. No. 4, p. 108.
‡ Histoire de l'Académie depuis 1686–1699, t. ii. (Paris, 1733) p. 19.
§ Mém. de l'Acad. depuis 1686–1699, t. vii. 2 (Paris, 1729) p. 206.
‖ Journal des Observations physiques, t. i. (Paris, 1714) p. 425.

the relative positions of the components. The remarks of both these observers are interesting. Richaud says:—"Regardant à l'occasion de la Comète plusieurs fois les pieds du Centaure avec une lunette d'environ douze pieds, je remarquai que le pied le plus oriental et le plus brilliant étoit une double étoile aussi bien que le pied de la croisade; avec cette différence, que dans la croisade une étoile paraît avec la lunette notablement éloignée de l'autre; au lieu qu'au pied du Centaure, les deux étoiles paraissent même avec la lunette presque se touche; quoique cependant on les distingue aisement."

These stars were regarded not as in real proximity, but accidentally in the same visual line—one far beyond the other; and this belief accounts for the fact that such pairs were not searched for, their discovery being accidental. We find that immediately their true character was only even suspected, the number of known systems increased at a very rapid rate. It is true that Lambert in 1761 * maintained that the stars were suns analogous to our Sun, and were accompanied by a retinue of planets and comets; and the Rev. John Michell in 1767 † found by the application of the theory of chances that the grouping of stars was scarcely accidental, and that double stars found by the telescope were for the most part binary systems. These, however, were mere speculations of one or two individuals.

In 1779 appeared a small book entitled "De novis in Cœlo sidero Phænominis in miris stellarum fixarum comitibus," by Christian Mayer ‡, wherein he speculates as to the possibility of small suns revolving around larger ones, but of course he could give no evidence. Mayer was a Jesuit Father observing at Mannheim with an 8-foot Bird mural quadrant, using a power of 85. He collected all double stars known down to the year 1781, and by adding his own discoveries formed a list of 89 pairs. This Catalogue was published in Bode's 'Astronomische Jahrbuch,' 1784: and as this may not be easy of access the following table (p. 90) will show the form employed (the stars are, of course, selected from various parts of the complete list).

It will be seen that the quantities are very rough and afford no basis for his speculations. Indeed his remarks show that he was rather thinking of proper motions, for he says:—"Double stars are those which are single to the naked eye, but which are separated by a less or greater magnification, often only by means of a very good telescope, into two stars a few seconds apart. . . . By means of careful observation of double stars it is possible to discover proper motions." The positions, in the last column, of the

* 'Cosmologische Briefe über Einrichtung des Weltbaumes,' J. H. Lambert, 1761.

† Phil. Trans. vol. lvii. pp. 231-264, "An Inquiry into the probable Parallax and Magnitude of the Fixed Stars from the Quantity of Light which they afford us. . . ."

‡ Christian Mayer, 1709-1783.

Extract from Mayer's List.

('Astronomische Jahrbuch,' 1784.)

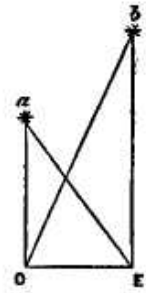
	Grösse.	Gerade Aufst.	Abweichung.	Unterschied		Abstand.	Stellung des Kleinern.
				in der Aufst.	in der Abw.		
		G. M.	G. M.	Sec.	Sec.	Sec.	
γ Widder	beyde 5 ter	25 22	18 13 N.	3	12	12	S.W.
γ Andromedæ ...	2 und 6 ter	27 36	41 16 N.	14	6	12	N.O.
α Widder	2 und 9 ter	28 40	22 24 N.	0	2	2	S.
Castor	2 und 9 ter	110 7	32 22 N.	10	4	9	N.W.
ζ Cancri	7 und 8 ter	119 52	18 19 N.	0	8	8	S.
γ Virginis	beyde 5 ter	187 37	0 13 S.	7	6	9	S.O.
ε Leyer	6 und 8 ter	279 13	39 27 N.	3	3	4	N.O.
ζ Leyer	beyde 6 ter	279 13	39 24 N.	0	2	2	S.

comes relative to the principal star are mere estimations. Measuring the angle with respect to the meridian was not possible nor considered important until the invention of Herschel's "revolving micrometer" in 1779.

Having disposed of these preliminaries, we can now turn our attention to Herschel's work; and for this purpose we must begin with his paper on the "Parallax of Fixed Stars," read before the Royal Society, 1781, December 6.

He points out that "to find the distance of fixed stars has been a problem which many eminent astronomers have attempted to solve"; and that the cause of non-success was due in a great measure to the inherent difficulties of the methods adopted. In general, the method of zenith-distances labours under the following difficulties: refractions imperfectly known; change of Earth's axis arising from nutation; precession and other causes not accurately known.

He then suggests the following method:—"Let O and E be two opposite points of the annual orbit, taken in the same plane with two stars, *a* and *b*, of unequal magnitudes. Let the angle *a*O*b* be observed when the Earth is at O, and let the angle *a*E*b* be also observed when the Earth is at E. From the differences in these angles, if any should be found, we may calculate the parallax of the stars, according to a theory that will be delivered hereafter. These two stars, for reasons that will soon appear, ought to be as near each other as possible, also to differ as much in magnitude as we can find them."



He then goes on to say that Galileo and others had suggested and tried this method, but had not avoided those errors because they had not chosen stars very close. The present

method he shows to be free from the defects above enumerated, and states that parallaxes of 0″·1 could be detected.

It is remarkable that this search after parallax should have been so prolific in discoveries, and yet of so little value to the main object. Bradley, labouring to obtain parallaxes, discovers the aberration of light and the nutation of the Earth's axis, and then Herschel, by the fact of observing two close stars in place of distant ones, lights upon the most unexpected and fruitful discovery of binary stars.

To return to Herschel's paper and the real ground-plan of the department of double-star work. The superstructure is not what the architect intended, and Herschel was himself the first to point out the discrepancy:—"As soon as I was fully satisfied that in the investigation of parallax the method of double stars would have many advantages above any other, it became necessary to look out for proper stars. This introduced a new series of observation. I resolved to examine every star in the heavens with the utmost attention and a very high power, that I might collect such materials for this research as would enable me to fix my observations upon those that would best answer my end. The subject has already proved so extensive and still promises so rich a harvest to those who are inclined to be diligent in the pursuit, that I cannot help inviting every lover of astronomy to join with me in observations that must inevitably lead to new discoveries. I took some pains to find out what double stars had been recorded by astronomers: but my situation permitted me not to consult extensive libraries, nor indeed was it very material; for as I intended to view the heavens myself, Nature, that great volume, appeared to me to contain the best catalogue upon this occasion. However, I remembered that the star in the head of Castor, that in the breast of the Virgin, and the first star in Aries had been mentioned by Cassini as double stars. I also found that the nebula in Orion was marked in Huyghen's 'Systema Saturnium' as containing several stars, three of which (now known to be four) are very near together.

"With this small stock I begun, and in the course of a few years' observations have collected the stars contained in my catalogue."

Some further remarks are interesting as showing the non-diffusion of useful knowledge at this period, and how extremely meagre and unsatisfactory were the few statements extant. Herschel's own notes, under exactly similar circumstances, I shall give presently. He says that "When at the Royal Observatory in 1781 the Astronomer Royal* showed me α Herculis as a double, stating that he had discovered it some years since. . . . . Mr. Hornby at Oxford mentions π Boötis as a double. . . . . It is a little hard on young astronomers to be obliged to discover *over again* what has already been discovered"†.

* Maskelyne. † W. Herschel, 1738–1822.

In this particular instance, however, there are few who could bring themselves to sympathise with Herschel. Had he even known of Mayer's catalogue, he might have been content to use these stars, and then we should have lost all his discoveries, all his measures, and with them also the early discovery of binary stars. This paper literally teems with the most useful information, and I cannot resist quoting still further from his notes on observing, which most double-star observers even now either have adopted or have fallen into the habit of using. And we must bear in mind that Herschel had no clock-work to keep his stars in the field; this had to be done with his hands.

"In settling the distances of double stars, I have occasionally used two different ways. Those that are extremely near each other may be estimated by the eye, in measures of their own diameters. For this purpose their distance should not much exceed two diameters of the largest, as the eye cannot so well make a good estimate when the interval between them is greater. This method has often the preference to that of the micrometer: for instance, when the diameter of a small star, perhaps not equal to half a second, is double the vacancy between the two stars. Here a micrometer ought to measure tenths of a second at least, otherwise we could not, with any degree of confidence, rely on its measures."

The remaining part of the paper is very interesting, but is more distinctly concerned with parallax.

In 1782, Jan. 10, Herschel published a catalogue of double stars for the use of observers studying parallax. These he divides into six classes:—

1. Stars requiring good telescopes and favourable circumstances to separate.
2. Stars proper for estimation by the eye or very delicate micrometer measures.
3. All stars more than 5″ and less than 15″ apart, and cannot be looked upon as free from the effects of refraction, &c.

"The 4th, 5th, and 6th classes contain double stars that are 15″ to 30″, 30″ to 60″, and 60″ to 120″ or more apart. Though these will hardly be of any service for the purpose of parallax, I have thought it not amiss to give an account of such as I have observed; they may, perhaps, answer another very important end . . . . Several stars of the first magnitude have already been observed, and others suspected, to have a proper motion of their own; hence we may surmise that our Sun, with all its planets and comets, may also have a motion towards some particular part of the heavens."

Here, again, observations of double stars may serve for a purpose other than parallax; but no idea as to their real future use seems to have been entertained. The determination of proper motions from micrometric measures is not regarded now with so much

favour, and yet I believe these observations capable of yielding very accurate results.

To return, this first catalogue of 269 double stars is of great importance, not only for the observations themselves, but for their exhaustive character and orderly arrangement. As an example of the amount of information and the thoroughness which characterized Herschel's work, one excerpt from the catalogue will suffice :—

"α Geminorum. Fl. 66. April 8, 1778.

"Double. A little unequal. Both W. The vacancy between the two stars, with a power of 146, is 1 diameter of S; with 222, a little more than 1 diameter of L; with 227, $1\frac{1}{2}$ diameters of S; with 460, near 2 diameters of L (see fig. 6); with 754, 2 diameters of L; 3168 the interval extremely large, and still pretty distinct. Distance by micrometer 5″·156. Position 32° 47′ n preceding. These are all a mean of the last two years' observations, except the first with 146."

The first class contained 17 stars, the second class 38, and amongst them the following :—

First Class.		Second Class.	
Star.	First observation.	Star.	First observation.
ϵ Boötis	1779, Sept. 9	α Geminor.	1778, April 8
ξ Ursæ Maj.....	1780, May 2	α Herculis	1779, Aug. 29
σ Coronæ	1780, Aug. 7	ρ Herculis	1779, Aug. 29
η Coronæ	1781, Sept. 9	ϵ Lyræ	1779, Aug. 29
ζ Cancri	1781, Nov. 21	ζ Aquarii	1779, Sept. 12

So far as I can ascertain, the first star measured belonged to the third class, viz. θ Orionis, 1776, November 11. After this paper had been read, Herschel saw Mayer's memoir, "De novis in Cœlo sidero Phænomenis," which is contained in the 4th volume of the 'Acta Academiæ Theodoro Palatinæ,' and acknowledges in a postscript that Mayer had the ideas before him. He also says that he purposely used the expression "double star" in preference to such words as comes, companion, satellite, "because, in his opinion, it is much too early to form a theory of small stars revolving around larger ones." In the words of W. Struve, these speculations "n'obtinerent point, à cette époque, l'approbation de l'astronome calme de Slough." He found that 31 of Mayer's stars were not in his catalogue.

An important paper of this calibre naturally set astronomers to work, and in the 'Philosophical Transactions,' 1783, November 27,